PATENT SPECIFICATION

1,065,542

Date of Application and filing Complete Specification: November 4, 1963. No. 43394/63

Complete Specification Published: April 19, 1967.

Index at Acceptance:—E1 A1C; B8 J (1, 3, 7).

Int. Cl.:—E 04 g 21/14 // B66f.

COMPLETE SPECIFICATION

DRAWINGS ATTACHED

Method and Equipment for Erecting Multi-Storey Building Structures

I, ERIK JOHAN VON HEIDENSTAM, a Swedish subject, of 58, Regeringsgatan, Stockholm, Sweden, do hereby declare the invention, for which I pray that a patent may be granted to me, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The present invention relates to an improved method of erecting a multi-storey building structure by the so-called lift-slab technique and to equipment for carrying out the method.

When erecting a building with the so-called lift-slab technique the slabs, which will form the floors of the upper storeys and the roof of the building, are fabricated at a base level upon one another directly below the position which the floor-slabs are to occupy in the erected building structure so that a stack of floor-slabs are formed at this base level. The base level, at which the slabs are cast upon one another on a ground plate, coincides normally with the ground level or the level of the ground floor in the building, but may lie below or above the ground level and e.g. coincide with the level of a basement floor in the building or with the level of the first or second storey in the building. In the last-mentioned case the first storey or the first and the second storeys respectively of the building must be erected previous to the casting of the slabs for the upper storeys of the building. Previous to or after the casting of the floor-slabs vertical load bearing columns are erected, which are to form permanent load bearing members in the building structure. In addition to these comparatively slender load bearing columns also other vertical load bearing members of the building structures may be erected, as e.g. certain load bearing walls, staircase-towers, elevator towers or the like.

In high buildings having a plurality of storeys the load bearing columns must normally consist of several sections disposed upon one another and spliced together, said sections being normally called the first tier, the second tier etc. of columns. When the column comprises two or several tiers of columns disposed upon one another, at first only the lowermost or first-tier columns are normally erected. The floor-slabs are made in as large sections as possible and preferably so that each floor-slab covers the entire area of the corresponding storey in the building, due to which the slab plates will have to cooperate with a large number of load bearing columns; the plurality of them being situated in openings provided in the slab plates.

When the slabs have set after the casting, they are lifted up by means of jacks either one after the other or in groups along the vertical load bearing columns and any other load bearing members of the building structure that may have been pre-erected, until the slabs have been raised to their intended final positions in the building structure, where they are attached to the columns and those other load bearing members if any.

The invention is primarily concerned with the lifting of the slabs along slender vertical load bearing columns of the type mentioned above. The invention can, however, also be used for the erection of building structures, in which in addition to such load bearing columns also other vertical load bearing members, as e.g. walls, staircase tower, elevator towers, are present, along which the slabs are to be raised. In such cases the method according to the invention can be used for the lifting of the slabs along the load bearing columns as well as along the other load bearing members or alter-

[Price 4s. 6d.]

natively used only for the lifting of the slabs along the load bearing columns or the majority thereof, whilst the lifting of the slabs along the other load bearing members and possibly along some of the columns is carried out in some other suitable way.

In the method previously most frequently used for lifting the slabs one has mounted jacks, normally hydraulic jacks, on the top of the load bearing columns or the erected tiers thereof and these jacks have been provided with lifting rods hanging down from the jacks parallel with the columns. The lower ends of these lifting rods have thereafter been connected to one or several of the slabs on the ground level and subsequently lifted together with the attached floor-slabs along the columns by the jacks. When the slabs attached to the lifting rods have been raised to their desired position, the slabs have been connected to the load bearing column and the lifting rods have been disconnected from these slabs and lowered by means of the jacks and connected to one or several of the slabs remaining on the ground level for the lifting of these slabs. This operation has been repeated until all slabs are raised from the ground level. If the load bearing columns are already from the beginning erected to their total height in the building, all floor-slabs can in the manner described above be raised to their final intended positions in the building structure and in these positions be permanently attached to the columns. In higher buildings, where at first normally only the lowermost tier of columns is erected, those floor-slabs which do not have their final position within this first tier of columns are lifted to a position immediately below the top of the first tier and are in these positions only temporarily connected to the columns. Thereafter the next tier of columns is erected and those slabs which are temporarily parked near the top of the first tier are by means of the jack equipment lifted further along the next, newly erected tier of columns.

This previously used method has, however, several very serious disadvantages, which are primarily caused by the fact that the jacks are mounted on the top of the load bearing columns of the erected tiers of the columns. As the height of each tier of columns normally corresponds to the height of 3 to 4 storeys in the building, it is evident that the mounting and adjusting of the jacks on the top of the column is time-consuming and dangerous work. The other parts of the lifting equipment, as e.g. the hydraulic tanks, hydraulic pumps and the control means, will, however, occupy a considerable area and must consequently be mounted on the uppermost floor-slab in the stack of slabs fabricated at the ground level or even on the ground itself beside the building structure to be erected.

Due to this it will be necessary to have long flexible hydraulic tubes between the jacks on the top of the columns and the parts of the lifting equipment mounted on the uppermost floor-slab or the ground respectively and these hydraulic tubes are very expensive and get easily damaged. Often it is also necessary to have electric signal conductors between the jacks and the control means arranged upon the uppermost slab and all these long hydraulic tubes and electrical conductors get easily entangled and pinched during the lifting operation.

When the load bearing columns consist of several tiers of columns spliced together and at first only the lowermost tier of columns is erected, it is evidently not possible with this previously used lifting method to erect the next tier of columns until the lifting of the slabs along the lowermost tier of columns has been completed and the jacks have been removed from the top of these first-tier columns. When the next tier of columns has been erected, the jacks must be remounted and readjusted on the top of the columns, before the lifting of the slabs can be continued. The erection of a new tier of columns upon a previously erected tier of columns will consequently require a considerable time and a lot of work, and consequently an extensive and effective use of the expensive jack equipment will be impossible. Also during this operation of dismounting and remounting the jacks upon the top of the columns the long flexible hydraulic tubes may easily be damaged.

A further serious disadvantage of this previously used lifting method is caused by the fact that each column must during the lifting of the slabs be loaded to its entire length, due to which the Euler conditions will be unfavourable and the risk of buckling of the columns considerable if the height of the tiers of columns is large, particularly when the uppermost slab is raised. On the other hand, however, it is advantageous if the height of each tier of columns is large, as this will give a small number of splicing operations and as the total costs for the manufacture of the supporting column will be smaller if the length of each column section is large. This is particularly true, when the columns are made of prestressed concrete.

Another method for lifting the slabs along the load bearing columns has also been previously used. In this method the load bearing columns are provided with permanent gear or tooth racks, along which the jacks can climb up along the columns while lifting a number of slabs connected to the jacks.

This method has certainly the advantage that the load bearing columns will not be loaded to their entire length but only in the part situated below the uppermost floor-slab, due to which the danger of buckling of the columns will be considerably smaller than in the lifting method described above. The method has, however, the serious disadvantage that the load bearing columns will be very expensive due to the permanent gear or tooth racks for the jacks. Further all the slabs must be lifted from the ground level at the same time in one single lifting operation, due to which the jacks must be very strong and will become correspondingly expensive. If one does not wish to lift all the slabs from the ground level at the same time, the jack equipment must evidently, when some of the slabs have been raised along the load bearing columns, be dismounted from the uppermost slab and remounted on the uppermost one of the slabs still remaining on the ground level. Such an operation is of course very time- and work-consuming.

In the method according to the present invention all the disadvantages of the previously used methods for lifting the floor-slabs, when erecting a building structure with the so-called lift-slab techniques, are eliminated and the method according to the invention makes it possible to lift the slabs to their final positions in the building structure very rapidly and with a minimum of manual work. In the method according to the invention one uses for the lifting of the slabs along the load bearing columns a plurality of reversible, preferably hydraulic, jacks of the type which cooperates with a lifting rod and is capable of moving a load attached to the jack in either direction along the lifting rod or alternatively moving the lifting rod together with a load attached to the rod in either direction relatively to the jack. The jacks are disposed close above the uppermost slab to be lifted and adjacent to the different load bearing columns. For the first lifting step the jacks are connected to the uppermost slab and possibly also to one or several of the slabs immediately below the uppermost slab, whilst the lifting rods are connected to the load bearing columns at a predetermined point above the uppermost slab, after which the jacks are started to move upwards along the stationary lifting rods, thereby liftitng the uppermost slab and any additional slabs connected to the jacks along the load bearing columns, to a point immediatey below the point of connection for the lifting rods to the columns, where the lifted slabs are attached to the columns. Thereafter the lifting rods are disconnected from the load bearing columns and their lower ends are connected to one or several of the uppermost slabs still remaining on the ground level, after which the jacks, which are now stationary, are operated to lift the lifting rods and the slabs connected thereto along the columns to the desired positions for these lift-slabs, in which positions the slabs are attached to the columns. Before the lifting step last described it is preferable to disconnect the jacks from the slabs first lifted and attached to the columns and instead to connect the jacks directly to the columns. In this way the slabs first lifted and attached to the columns will not be loaded during the second lifting step by the weight of the slabs lifted during this second lifting step. When the second lifting step has been completed, the lifting rods are disconnected from the slabs raised during this lifting step and are lowered so that their lower ends can be connected to any slabs still remaining on the ground for lifting these slabs in the same manner. This lifting operation is repeated until all slabs have been lifted from the ground level and during all the lifting steps those slabs which are raised to their final positions in the building structure are attached to the load bearing columns in these positions, whilst the other slabs, if any, are raised to immediately below the initial point of connection for the lifting rods to the columns and are only temporarily attached to the columns at this point.

For the further lifting of slabs only temporarily connected to the load bearing columns the lifting rods are again connected to the columns at a higher point, after which the jacks are disconnected from the columns and reconnected to the uppermost or the uppermosts of the slabs and started to move up along the now once more stationary lifting rods, thereby lifting the uppermost slabs connected to the jacks to immediately below the new point of connection for the lifting rods to the columns, where the uppermost slabs are again attached to the columns. Thereafter the jacks are, in the same way as described before, disconnected from the slabs last lifted and instead connected to the columns, whilst the lifting rods are disconnected from the columns and connected with their lower ends to any still remaining slabs temporarily attached to the columns below the first point of connection for the lifting rods, so that these slabs can be lifted further by means of the lifting rods.

It is preferred to arrange also all other parts of the lifting equipment besides the jacks, as e.g. hydraulic tanks, hydraulic pumps and control means, on the uppermost slab to be raised, as this will give considerable advantages.

When erecting building structures which comprise in addition to the normal load

bearing columns also other load bearing members, as e.g. walls, staircase towers, elevated towers or similar members, which are used for the lifting of the slabs, the lifting method according to the invention can be used not only at the normal load bearing columns but also at the other load bearing members. It is, however, also quite possible, when erecting such a building structure, to use the method according to the invention only at the load bearing columns, whilst the lifting of the slabs along the other load bearing member is carried out in some other way, e.g. by means of jacks mounted on top of the other load bearing members in the manner of the previously used lifting method described above.

The method according to the invention has the obvious advantage that the lifting jacks as well as all other parts of the lifting equipment can be mounted upon the uppermost slab to be raised, due to which the mounting and adjusting of the lifting equipment can be carried out in a short time without any hazard. Furthermore, no long and expensive, flexible, hydraulic tubes are required between the jacks and the hydraulic pumps, but the hydraul network can consist almost completely of stationary pipe conduits arranged on the uppermost slab. If flexible hydraulic tubes are necessary adjacent to the jacks, which may possibly be moved somewhat relative to the uppermost slab during certain steps of the lifting process, these hydraulic tubes will be very short. Due to this it will also be possible, without heavy costs, to give the hydraulic network a larger flow area, whereby the losses in the hydraulic network are reduced.

Furthermore, the upper ends of the load bearing columns will be completely free from the lifting equipment so that the erection of the next tier of columns can be carried out at the same time as the slabs are lifted up along the lower tier of columns. Consequently, the lifting process does not have to be interrupted for the erection and splicing of the tiers of columns, due to which the total time for lifting the slabs can be considerably reduced. Furthermore no dismounting whatsoever of the jacks and subsequent remounting and readjusting of them in another position will be necessary, when a new tier of columns is erected upon a previously erected tier of columns. This results in an addition, very considerable reduction in the time and amount of work necessary for the lifting of the slabs.

A further advantage of the lifting method according to the invention is that the load bearing columns do not have to be loaded to their entire length during the lifting of the uppermost slab. The first point of connection for the lifting rods and the jacks respectively during the lifting of the slabs can quite simply be located at only a portion of the total height of the columns or the first erected tier of columns, so that the danger of buckling of the columns is reduced. It is consequently quite possible to give the tiers of columns the largest convenient height, to reduce the number of splicing operations for the columns and the costs of manufacture of the columns. Another advantage is that the lifting rods can be shorter than the total height of the tiers of columns, whereby the manufacture, the handling and the transport of the lifting rods will be simplified and less expensive.

It is preferable to arrange two or several jacks at each load bearing column symmetrically around the column, whereby a symmetrical loading of the column during the lifting of the slabs can be easily ensured.

Means for supplying pressure medium to and removing it from the jacks as well as control means for the operation of the jacks are preferably arranged upon the uppermost lift-slab so that the entire lifting equipment is disposed on this slab.

For the erection of building structures comprising in addition to normal load bearing columns also other vertical load bearing members, as staircase towers, walls and similar members, the lifting equipment can in addition also comprise jacks for the lifting of the slabs relatively to the other load bearing members, in which case the last mentioned jacks can be arranged either in the same way as the jacks at the load bearing columns or in some other way, e.g. on the top of said other loading bearing members.

The invention will be further described by way of example only in conjunction with the accompanying drawings in which:

Figures 1A and 1B are schematic illustrations of different stages in the process of lifting the slabs along vertical load bearing columns consisting of two tiers of columns disposed upon one another and spliced together, when erecting an eight-storey building structure by the method according to the invention. Figures 1A and 1B show only one of the load bearing coloumns in the building structure and those parts of the lifting equipment which cooperate with this column. The arrangement of the lifting equipment at the other load bearing columns can be exactly or substantially the same. The number of load bearing columns is determined **inter alia** by the dimension and the weight of the slabs to be raised and by the general construction of the building structure and does not influence the lifting method nor does it affect substantially the arangement of the lifting equipment. Nor is the lifting method or those parts of the lifting equipment concerned with the lifting of the slabs relative to the load bearing columns sub-

stantially changed, if the building structure in addition to the normal load bearing columns also comprises other types of load bearing members, as e.g. walls, staircase towers or elevator towers, which are used for the lifting of the slabs.

Fig. 2 is a detailed and partially sectional illustration in a larger scale of the portion of the equipment shown within the frame A in Fig. 1A-a.

Fig. 3 is a cross section through the same portion of the equipment along the line III-III in Fig. 2;

Fig. 4 is a detailed elevation in a larger scale of the portion of the equipment shown within the frame B in Fig. 1A-a, and

Fig. 5 is a cross section through the portion in Fig. 4 along the line V-V in Fig. 4.

The lifting equipment shown comprises for each load bearing column 1 two hydraulic, reversible jacks 2 each cooperating with a respective lifting rod 3. The lifting rods are threaded and each jack comprises a hydraulic cylinder consisting of end plates 4, 5 and a cylindrical casing 6. Within the hydraulic cylinder a piston 7 is movable in the longitudinal direction of the lifting rod. Further, the jack comprises two nuts 8 and 9 rotatable around the lifting rod 3. The upper nut 8 cooperates with the piston 7, whilst the lower nut 9 cooperates with the lower end plate 5 or an additional end plate 10, which is permanently connected to the hydraulic cylinder of the jack. The upper nut 8 is connected to a sprocket wheel 11 rotatable in the upper end plate 4 in such a way that the nut 8 can be displaced in an axial direction but not rotated relatively to the sprocket wheel 11. The lower nut 9 is in the same way connected to a sprocket wheel 12 rotatable in the lowermost end plate 10. The different parts of the jack casing are kept together by four bolts 13. The jack casing is provided with four additional bolts 14, which may aid in keeping the jack casing together but which primarily are intended for the connection of the jack to a load or a support and with this object these bolts are so long that they project above the upper end and below the lower end of the jack.

The invention is, however, not restricted to the use of jacks of this type but also other jacks are usable, provided they are capable of moving a load in either direction along a lifting rod or alternatively of moving the lifting rod together with a load in either direction relatively to the jack. It should also be pointed out that a jack of the type shown in the drawing may comprise several, cooperating, hydraulic cylinders instead of only one, as shown in the drawing.

The two jacks 2 at the load bearing column 1 are disposed symmetrically relatively to the column on opposite sides thereof and carry a U-shaped console 15, which is attached to the jacks preferably in such a manner that each jack can be pivoted relative to the console about a vertical axis through the point of connection between the console and the jack. The console 15 supports two, preferably hydraulic, torque motors 16 and 17. The output shaft of the upper torque motor 16 is provided with a sprocket wheel 18, which by means of an endless chain 19 is coupled to the sprocket wheels 11 on the two jacks 2. The console 15 supports three guide wheels 20, 21, 22 for the chain 19. In the same manner the lower torque motor 17 is provided with a sprocket wheel 23, which by means of a chain 24 is coupled to the lower sprocket wheels 12 of the two jacks 2. In Fig. 2, the sprocket wheels 18 and 23 are hidden behind chains 19 and 24 respectively. The upper nuts 8 of the two jacks can consequently be rotated by the torque motor 16, whilst the lower nuts 19 of the jacks can be rotated by the torque motor 17. The torque motors 16, 17 can form a single structural unit or may be replaced by a single torque motor having two independently rotatable output shafts. The torque motors are of such a type that they can rotate the nuts of the jacks in either direction around the lifting rods.

The jacks and the torque motors are in a manner not shown in the drawing connected to an equipment for supplying and removing pressure medium to and from the jacks and the torque motors respectively. This equipment can be of a conventional type or any other suitable type and is preferably located on the uppermost floor-slab I. The control equipment for the control of the operation of the lifting equipment is preferably also located on the uppermost floor-slab I. This control equipment may be connected through electrical signal conductors to signal means arranged on the jacks for supplying information to the control equipment regarding the position and the state of operation of the jacks.

The jacks can move in either direction along the lifting rods or alternatively move the lifting rods in either direction relatively to the jacks. If the jack is to move upwards along the lifting rods, which in this case are assumed to be stationary, pressure medium is supplied to the hydraulic cylinder of the jack above the piston in the position of the jack shown in Fig. 2. The piston will now rest against the upper nut 8 and consequently be stationary with respect to the lifting rod, whilst simultaneously the jack casing is lifted upwards relatively to the lifting rod. During this process the upper nut 8 is locked and can consequently not be rotated by the torque motor 16. The lower nut 9 on the other hand will be rotated by the torque motor 17 upwards the lifting rod

a distance substantially corresponding to the displacement of the jack casing relatively to the lifting rod. The nut 9 may be provided with means for limiting its rotation so that the nut is rotated a precise predetermined distance. Thereafter pressure medium is supplied to the jack below the piston 7, whilst pressure medium is discharged from the space above the piston. During this process the jack casing will be resting upon the lower nut 9 and consequently be stationary relative to the lifting rod. The piston 7, however, will be lifted upwards relative to the rod and in doing so release the nut 8, which is rotated by the torque motor 16 a distance substantially corresponding to the displacement of the piston relative to the lifting rod 3. The jack has thus returned to the state shown in Fig. 2 but has been moved a distance upwards the lifting rod 3 corresponding to the length of the mutual movement between the piston and the casing of the jack. It is evident that the jack can in a corresponding way be moved downwards along the rod, if the nuts are rotated in the opposite direction downwards the rod and the pressure medium is supplied to the space below the piston during the working strokes and to the space above the piston during the return strokes and provided that the movement of the jack downwards along the lifting rod is counteracted by a force directed upwards.

In the above description of the operation of the jack it has been assumed that the lifting rod is stationary and the jack movable. It is evident, that, if instead the jack is stationary, it can move the rod either upwards relative to the jack or downwards relative to the jack provided that the movement of the lifting rod is counteracted by a force directed against the direction of movement of the rod.

As shown in Fig. 2 the jacks can be connected to the two uppermost lift-slabs I, II by means of the lower ends of the connection bolts 14. These bolts can be inserted through openings in the uppermost lift-slabs I, II and be provided with nuts 24, 25 respectively on the lower sides of the lift-slabs so that the jacks, if they are started to move upwards the lifting rods 3 while these are stationary, will lift the two uppermost lift-slabs I, II. The lower ends of the lifting rods can be lowered through openings 26 in the lift-slabs, as shown in Fig. 2. The lower end of the lifting rods can be provided with a head 27, consisting e.g. of a nut threaded on the lower end of the lifting rod. The openings 26 in the lift-slabs III-VIII have the general shape of a key-hole so that the heads 27 on the lifting rods 3 can engage anyone of these lift-slabs, e.g. the lift-slab V as shown with dotted lines in Fig. 2. If the jacks are stationary relative to the columns 1, any desired number of the lift-slabs III-VIII can consequently be lifted along the columns by means of the lifting rods of the jacks. Around the openings provided in the lift-slabs for the load bearing columns 1 steel collars are normally cast into the lift-slabs, in which collars the openings for the lifting rods 3 and the connection bolts 14 of the jacks can be provided.

As shown in Figs. 4 and 5 the lifting equipment comprises also for each load bearing column 1 a connection member 28, which can be moved along the column and temporarily connected to the column. In the embodiment of the invention shown in the drawing this connection member 28 consists of an inner frame 29 surrounding the column 1 and displaceable along the column. This frame can be stationarily attached to the column in certain predetermined positions, e.g. by bolts 30 inserted below the frame 29 into recesses in the flanges of the column 1. There are, however, several other manners, in which the frame 29 may be temporarily attached to the load bearing column 1. The connection member 28 comprises further an outer frame 31, which is connected to the inner frame 29 through pivots 32, so that the outer frame 31 is tiltable relative to the inner frame 30 about an horizontal axis, central relative to the load bearing column. The two opposite sides 33 of the outer frame 31, which are situated above the jacks associated with the load bearing column, are rotatable relative to the outer frame 31 about horizontal pivots 34 which are parellel with the pivots 32. The side members 33 are provided with vertical through-openings, through which the lifting rods 3 are inserted. The lifting rods are provided with nuts 35 resting against the upper side of the side members 33 of the frame 31 so that the lifting rods 3 are supported by and hang down from the connection member 28. The side members 33 of the frame 31 are on their lower sides provided with connection plates 36, which are provided with openings fitting the upper ends of the connection bolts 14 of the jacks. If the jacks are moved to a position immediately below the connection member 28, the bolts 14 of the jacks can consequently be inserted through the openings in the connection plates 36 and be provided with nuts 37 on the upper side of the connection plates so that the jacks will be hanging in the connection member 28 and thus be connected to the load bearing column 1. Due to the fact that the outer frame 31 of the connection member 28, in which the lifting rods 3 and the jacks 2 are alternatively hanging during the lifting operations, is tiltable about a horizontal axis central to the load bearing column and that the side members 33 of the frame 31, in which the lifting rods and the jacks respectively are hanging,

are rotatable relative to the frame 31 about horizontal axes, symmetrical loading of the load bearing column 1 during the lifting operations is ensured.

Figures 1A and 1B show the different stages of the lifting process, when the lift-slabs are raised along the load bearing columns by means of the lifting equipment described above and with the lifting technique according to the invention for the erection of a 8-storey building structure having load bearing columns consisting of two tiers of columns 1a and 1b disposed upon one another and spliced together. Fig. 1A-a shows schematically the starting position for the lifting process, in which position all eight lift-slabs I-VIII are disposed upon one another at the ground level in the positions in which they have been fabricated. It should be noted that the erection of the columns and the construction of the floor slabs may be carried out in any desired order. In Fig. 1, only the first-tier column 1a has been erected and the connection member 28 is connected to the first-tier column 1a at a height corresponding to about three storeys. The lifting rods 3 are by means of the nuts 35 hanging in the side members 33 of the connection member 28 in the manner shown in Fig. 4, whilst the jacks 2 are hanging on the lifting rods 3 and are connected to the two uppermost lift-slabs I, II by the lower ends of their connection bolts 14 in the manner shown in Fig. 2.

The lifting equipment can be mounted in the following way: The connection member 28 is arranged on the first-tier column 1a previous to the erection thereof. When the first-tier column 1a has been erected and all lift-slabs I-VIII have been fabricated at the ground level, the lifting rods are inserted from below through the openings provided for them in the tiltable side members 33 of the connection member 28. For this operation the connection member 28 may be temporarily raised a distance along the first-tier column 1a and subsequently lowered again and connected to the first-tier column 1a in the desired position. Thereafter the tiltable frame 31 of the connection member 28 is adjusted in an exactly horizontal position and temporarily locked to the inner frame 29 in this horizontal position. Thereafter the two lifting rods 3 are adjusted so that they are disposed on exactly the same height and in exactly the same position with respect to their threads. During and after the adjustment of the lifting rods these can be kept in the desired position by suitable holding means supported by the uppermost lift-slab. In the adjusted position of the lifting rods the lower ends of the rods shall be raised a substantial distance above the uppermost lift-slab so that the jacks can be disposed below the lower ends of the lifting rods. When the lifting rod has been adjusted in the manner described above, the two jacks 2, which are interconnected by the console 15, are placed below the lower ends of the lifting rod and adjusted so that they are disposed at the same height and so that their pistons and nuts are in prescribed positions. During this operation the jacks may be supported from the uppermost lift-slab by a suitable supporting means adjustable in the vertical direction. Thereafter the two lifting rods are lowered by means of their holding means, until the lower ends of the rods engage the upper nuts of the jacks. The torque motor 16 for the upper nuts in the jacks can now be started so that the lifting rods are threaded downwards through these nuts, until they engage the lower nut in the jacks, after which also the lower torque motor 17 for the lower nuts in the jacks can be started so that the lifting rods are threaded downwards through the jacks. The holding means for the lifting rods can now be removed and the nuts 35 (Fig. 4), which preferably are split in two halves, are arranged round the lifting rods and tightened against the upper side of the frame 31 so that the lifting rods will be hanging down from the connection member 28. It is now possible to remove the supporting means between the jacks and the uppermost lift-slab so that the jacks will be hanging on the lifting rods. The jacks are now lowered along the lifting rods e.g. by simultaneous rotation of the two nuts in each jack in the same direction. If necessary, the lifting rods 3 can be prevented from rotating with the nuts by interconnecting the upper ends of the lifting rods projecting above the connection member 28 through a U-shaped yoke plate or a similar member. The two jacks are lowered together along the lifting rods 3, until the lower ends of the connection bolts 14 have been inserted through the two uppermost lift-slabs I, II to the position shown in Fig. 2. During this operation the nuts 24 and 25 are threaded on the connecting bolts 14. As shown in the drawing the nuts are preferably arranged upon the connection bolts 14 in such manner that the nuts 24 are somewhat spaced from the lower side of the second lift slabs II. Alternatively the two uppermost lift-slabs I, II may be provided with necessary bolts during the fabrication of the lift-slabs, in which case these bolts are spliced to the lower ends of the connection bolts 14, e.g. by threaded sleeves, during the mounting of the jacks. Finally, the outer frame 31 of the connection member 28 is released so that it can tilt relative to the inner frame 29 and the load bearing column 1 about the pivots 32.

When the lifting equipment has been

mounted, e.g. in the manner described above, in the position shown in Fig. 1A-a, the lifting operation for the lift-slab is started. At first the jacks are started to move upwards along the lifting rods 3 pendent from the connection member 28, whereby the jacks by the lower ends of their connection bolts 14 will bring along the two uppermost lift-slabs I and II together with the lifting equipment arranged upon the uppermost lift-slab I. Due to the fact that the nuts 24 on the blots 14 are abutting the uppermost lift-slab I, whilst the nuts 25 are somewhat spaced from the second lift-slab II, the uppermost lift-slab I will be separated from the second lift-slab II, before the lastmentioned lift-slab is separated from the lift-slab III. In this way the lift-slabs I and II are separated somewhat from one another at the same time as they are lifted from the ground level. In the example of the lifting technique according to the invention illustrated in Fig. 1A and 1B the connection member 28 is at first connected to the first-tier column 1a at a height corresponding only to three storeys, in spite of the fact that the total height of the first-tier column is five storeys. In this way the danger of buckling of the column is considerably reduced during the initial lifting operation. There is, however, in principle nothing preventing the connection member 28 from being from the beginning connected to the upper end of the first-tier column when this is possible with respect to the Euler conditions of the load bearing columns.

When the two uppermost lifting-slabs I, II together with the jacks 2 and the lifting equipment arranged upon the uppermost lift-slabs have been raised along the lifting rods 3 in the manner illustrated in Fig. 1A-b to a position immediately below the connection member 28, the lift-slabs I, II are temporarily connected to the load bearing columns 1a. This connection can be made in any suitable conventional maner, e.g. by lowering lift-slabs onto horizontal support beams temporarily inserted in recesses in the load bearing column 1a below the lift-slabs. Several different methods for temporarily connecting one or several lift-slabs to vertical load bearing colums are known in the prior art. Thereafter the jacks are lowered somewhat so that they are unloaded and disengaged from the two raised lift-slabs I, II, i.e. so that the nuts 24, 25 on the connection bolts 14 of the jacks are spaced somewhat from the lower surface of these lift-slabs. During the last portion of the lifting step for the lift-slabs I, II the upper ends of the connection bolts 14 of the jacks have been inserted through the openings in the connection plates 36 of the connection member 28. On the upper ends of the bolts 14 nuts 37 are now tightened against the connection plates 36 in the manner shown in Fig. 4 so that the jacks will be hanging in the connection member 28. Simultaneously, the lifting rods are disconnected from the member 28 so that they will hang in the jacks and their lower ends are then connected to the lift-slab V remaining on the ground level. The lastmentioned operation is made by applying the nuts 27 (Fig. 2) on the lower ends of the lifting rods, after which the lifting rods are lowered, e.g. by a simultaneous rotation in the same direction of the two torque motors 16, 17 in the jacks, until the nuts 27 on the lifting rods can be brought into engagement with the lift-slabs V, as shown with dotted lines in Fig. 2. The lifting rods can be inserted downwards through the keyhole-spaced openings 26 in the lift-slabs III, IV and V due to the fact that the lifting rods are sufficiently elastic so that their lower ends can be separated somewhat from one another. The lifting equipment is thus now in the position shown in Fig. 1A-c.

The jacks are now started to lift the lifting rods 3 and thus the lift-slabs III, IV, V along the first-tier column 1a, as illustrated in Fig. 1A-d. During this lifting operation the jacks operate in the opposite direction compared with the operation of the jacks during the lifting step in Fig. 1A-b. When the lift-slabs III-V together with the lifting rods have been raised to a position immediately below the lift-slabs I,II initially raised, the lift-slabs III, IV, V are temporarily connected to the first-tier column 1a, after which the lifting rods 3 are lowered again alone, as shown in Fig. 1A-e. The lowering of the lifting rods can be carried out in the manner described above or alternatively by starting the jacks to operate in the opposite direction as compared with the direction of operation during the lifting of the lifting rods together with lift-slabs connected to the rods. In this case braking means, preferably arranged e.g. upon the connection member 28, must however be applied against the two lifting rods so that the lowering of the rods s counteracted by a friction force, which is larger than the weight of the rod, whereby the jacks will be operating against a force in the normal way.

The lower ends of empty lifting rods are lowered downwards through the openings 26 in the lift-slabs VI, VII, VIII still remaining on the ground level, until the nuts 27 on the lower ends of the lifting rods can be brought into engagement with the lowermost lift-slab VIII.

The jacks are now once more started to lift the lifting rods 3 and thus the remaining lift-slabs VI-VIII along the first-tier

column 1a as shown in Fig. 1A-f. When during this lifting operation the lift-slabs reach the first storey the slabs are lowered onto preferably permanent connection means on the first-tier column 1a provided for the floor slab VIII of the first storey. The lower ends of the lifting rods are disengaged from this slab and instead brought into engagement with the lift-slab VII, after which the lifting of the lift-slabs VI-VII is continued by means of the lifting rods, until the slabs reach the second storey in the building structure, where the two slabs are lowered onto preferably permanent connection means provided on the first-tier column 1a for the floor-slab VII of the second storey. The lifting equipment is now in the position shown in Fig. 1A-g and all slabs have been raised from the ground level either to their final positions in the permanently connected to the columns (slabs VII, VIII) or to positions immediately below the connection point of the connection member 28 to the first-tier column 1a and in these positions temporarily connected to the columns (lift-slabs I-VI). The slab VI is temporarily resting upon the floor-slab VII, which is permanently connected to the load bearing columns.

The connection member 28 must now be moved to a higher position on the first-tier column 1a, preferably to the upper end thereof, so that the lifting of the slabs can be continued. For this purpose the jacks are disconnected from the connection member 28 by removing the nuts 37 on the upper ends of the bolts of the jacks and then the jacks are again connected to the uppermost slab I preferably by tightening nuts 38 on the bolts 14 of the jacks against the upper surface of the uppermost lift-slab I so that the jacks will be resting upon this slab. The connnection member 28 can be lifted to a higher position on the first-tier column 1a by first lowering the lifting rods 3 so that their upper ends are close to the connection member 28, after which the connection member 28 is attached to the lifting rods and these are lifted together with the connection member by means of the jacks, until the connection member is brought to its new position, in which it is reattached to the first-tier column 1a. Another method of raising the connection member 28 to a higher position is to connect the connection member to the lifting rods by means of nuts, which surround the lifting rods but are stationary relative to the connection member 28, after which the connection member, when it has been disconnected from the first-tier column 1a, can be raised upwards along the column by simultaneous rotation of the two rods 3, as shown in Fig. 1B-h. The lifting rods 3 can be rotated by temporarily locking the two nuts 8, 9 of the jacks 2 relative to the lifting rods 3 and subsequently rotating the nuts simultaneously and in the same directions by the torque motors 16, 17. In the type of jacks shown in Fig. 2 the nuts 8, 9 cannot be reached from the outside of the jacks, but the nuts can of course be locked relative to the lifting rods by locking the sprocket wheels 11, 12 relative to the lifting rods. In each jack only one of the nuts has to be locked relative to the associated lifting rod, if in the one jack the upper nut and in the other jack the lower nut is locked and simultaneously the two driving chains 19 and 24 for the upper and the lower nuts respectively are locked relative to one another so that they will move in synchronism. This can be easily obtained by locking one of the guide wheels for the upper chain 19 to a shaft on which the corresponding guide wheel for the lower chain 24 is permanently attached.

When the connection member 28 has been raised to the upper end of the first-tier column 1a, it is again connected to the column and the lifting rods are released from the connection between the connection member and the lifting rods used during the raising of the connection member 28. Then the nuts 35 on the lifting rods 3 are tightened against the upper side of the connection member 28 so that the rods are hanging in the connection member. The two jacks can now once more be started to move in a normal manner upwards along the lifting rods 3, whereby they will lift the two uppermost slabs I, II, which are hanging in the lower ends of the bolts 14 of the jacks, in the manner disclosed in Fig. 1B-i.

When the slabs I, II have been lifted to immediately below the upper end of the first-tier column 1a and in this position been temporarily connected to the column and the jack has been disengaged from these slabs and instead connected with the upper ends of the bolts 14 to the connection member 28, the lower ends of the lifting rods 3 are brought into engagement with the lift-slab IV, after which the jacks can be started to lift the lifting rods and the lift-slabs III, IV hanging therein, as shown in Fig. 1B-j.

When the slabs III, IV have been raised to a position immediately below the previously lifted slabs I, II and been temporarily connected to the first-tier column 1a, the lifting rods 3 are lowered in the manner previously described so that their lower ends can be brought into engagement with the slab VI, after which the jacks are started to lift the lifting rods and thus the two slabs V, VI, as shown in Fig. 1B-k. When during this lifting operation the slabs reach the third storey, the slab

VI is permanently connected to the first-tier column 1a and the lower ends of the lifting rods are disconnected from this slab and then brouhgt into engagement with only the slab V, after which this slab is lifted further to the fourth storey, where also this slab is permanently connected to the first-tier column 1a.

During this lifting operation it is preferred that the second-tier column 1b is erected and spliced to the first-tier column 1a so that the lifting of the slabs along the second-tier column 1b can be immediately started, as soon as the lifting of the slabs along the first-tier column 1a has been completed.

For the lifting of the slabs I-IV along the second-tier column 1b it is, however, necessary that first the connection member 28 is moved to the upper end of this second-tier column, which can be done in the manner previously described, by connecting the jacks to the uppermost slabs I, II so that they are resting upon the uppermost slab I and connecting the connection member 28 to the lifting rods by means of nuts stationary relative to the connection member, after which the connection member 28 is disconnected from the first-tier column 1a and the two lifting rods 3 are rotated by the nuts of the jacks and the torque motors 16, 17 so that the connection member 28 is threaded upwards along the lifting rods to the upper end of the second-tier column 1b; in the manner shown in Fig. 1B-1. The second-tier columns 1b are normally provided with temporary extension pieces 1c, as shown in Fig. 1B-m, to which the connection members 28 are connected.

When the connection member 28 has been connected to the temporary extension piece 1c and the lifting rods 3 are hanging in the connection member 28 through their nuts 3, the jacks 2 can be started to move upwards the lifting rods while lifting the two uppermost slabs I, II; as shown in Fig. 1B-m. When during this lifting step the lift-slabs I, II are lifted to the seventh storey, the slabs are lowered onto permanent connection means for the floor slab II, which is permanently connected in this final position to the second-tier columns 1b, after which the connection bolts 14 of the jacks are disengaged from this slab II and the jacks continue the lifting of only the slab I, until this is brought to the eighth and uppermost storey in the building, where the slab I is permanently connected to the second-tier columns 1b. The jacks are now immediately below the connection member 28 and can consequently with their connection bolts 14 be connected in the manner previously described to the connection member 28, at the same time as they are released from the slab I. Thereafter the lower ends of the lifting rods 3 are brought into engagement with the slab IV, after which the rods are lifted by the jacks 2 together with the slabs III, IV; as shown in Fig. 1B-n. When during this lifting operation the slabs reach the fifth storey, the slab IV is permanently connected to the first-tier columns 1a and is disconnected from the lower ends of the lifting rods, which are brought into engagement with the slab III, which is lifted further to the sixth storey in the building and there permanently connected to the second-tier columns 1b.

In this way all eight floor-slabs I-VIII have now been lifted from the ground level where they were fabricated, to their final positions in the building and in these positions been connected to the load bearing columns 1 in the building structure. Thereafter the entire lifting equipment, which is arranged upon the uppermost floorslab I now located at the eighth storey in the building structure, can be dismounted. This is a very simple operation, as the uppermost floor-slab I can serve as a working platform just as it has done during the entire lifting process for those operations which the lifting equipment has carried out.

It is obvious that the lifting technique according to the invention described above is applicable independently of the number of tiers of columns in the building structure as well as of the number of lifting steps within each tier of columns, i.e. the number of connection points for the connection members 28 within each tier of columns. It is also evident that the lifting technique according to the invention can also be used in connection with other types of vertical load bearing members than slender columns, as e.g. load bearing walls, staircase towers or elevated towers, in which case, however, the connection members for the connection of the lifting rods and the jacks respectively to the load bearing members as well as the arrangement of the jacks with respect to the load bearing members may require some modification.

WHAT I CLAIM IS:—

1. The method of erecting a multi-storey building having floor slabs connected to vertically extending load bearing members by the aid of a plurality of jacks each co-operating with an associated vertical lifting rod and being of a type permitting relative movement in both directions between the jack and its associated lifting rod, comprising the steps of:

a. erecting at least a lower tier of the load bearing members and constructing the floor slabs in a vertical stack at a base level below the upper ends of the load bearing members;

b. lifting said slabs to vertically spaced apart locations along the load bearing members by:

(1) so connecting the lifting rods to said load bearing members above said floor slabs as to prevent vertical movement of said lifting rods relative to said members;

(2) connecting said jacks to some of said floor slabs;

(3) so actuating said jacks as to move said jacks upwardly along said lifting rods and thereby lift the floor slabs to which said jacks are connected upwardly along said load bearing members;

(4) fixedly positioning the jacks relative to the load bearing members above the floor slabs;

(5) disconnecting said lifting rods from said load bearing members and fixing them to at least some of the remaining floor slabs; and

(6) so actuating said fixedly positioned jacks as to elevate said lifting rods relative to said jacks and thereby lift the floor slabs attached to said lifting rods relative to said load bearing members;

c. connecting the floor slabs to the load bearing members at said vertically spaced apart locations.

2. The method of claim 1, wherein, in the steps of paragraphs *b*(4)-*b*(6), the slabs are lifted in at least two groups, and said lifting rods are lowered relative to said jacks after all but the last group of slabs is lifted.

3. The method of claim 2, wherein said lifting rods are lowered by jacking them downwardly with said jacks.

4. The method of claim 1, 2 or 3 wherein in at least one of the steps of paragraphs *b*(3) and *b*(6) at least part of the floor slabs are lifted to elevations adjacent those at which said lifting rods are fixed to said load bearing members in the step of paragraph *b*(1); said lifting rods are thereafter fixedly connected to said load bearing members at higher elevations; and the steps of paragraphs *b*(2)-*b*(6) are repeated to lift to still higher positions at least part of the floor slabs first lifted to elevations adjacent those at which said lifting rods were originally fixed to said load bearing members.

5. The method of claims 4, wherein; said lifting rods are reconnected to said load bearing members at a higher elevation at least one additional time; and steps *b*(2)-*b*(6) are repeated to lift predetermined numbers of said floor slabs to elevations closely adjacent those at which said lifting rods are reconnected on successive occasions to said load bearing members.

6. The method of any of claims 1 to 5, wherein there are at least two jacks symmetrically arranged around each of said load bearing members to thereby impose symmetrical loads on said members.

7. The method of any of the preceding claims, together with the steps of: detachably connecting extensions to the tops of said load bearing members; and in at least one of the aforesaid lifting steps connecting the stationary ones of the lifting components to said extensions, whereby the uppermost of the floor slabs may be raised to a location at the upper ends of the load bearing members.

8. The method claimed in any of claims 1 to 7 in which in step *a* the complete load bearing members are erected.

9. The method claimed in any of claims 1 to 7 in which in step *a* only a first tier of the load bearing members is erected, and between steps *b*(6) and *c* at least a second tier of load bearing members is erected on said lower tier of load bearing members to increase the height of said members; and at least some of said floor slabs are lifted to levels above the first tier of said members by repeating the steps of paragraphs *b*(1)-*b*(6).

10. The method of claim 9, wherein the sequence of steps set forth in paragraphs *b*(1)-*b*(6) is repeated at least once for each tier of load bearing members.

11. The method claimed in any of claims 1 to 10 in which connecting members are provided for connecting said jacks and said lifting rods to said load bearing members, in which steps *b*(1) is performed by fixing said connecting members to the upper ends of the lifting rods, elevating said lifting rods with said jacks until said connecting members reach positions above the uppermost one of said slabs, and fixing said connecting members to said load bearing members at said elevated positions to thereby fixedly position said lifting rods relative to said load bearing members.

12. The method of claim 11, wherein, after step *b*(6), said connecting members are disconnected from said jacks and said load bearing members, and the steps of at least paragraphs *b*(1) to *b*(3) are repeated at least once to further elevate at least some of said floor slabs.

13. The method of claim 11 or 12, wherein said connecting member associated with each load bearing column comprises a first rectangular frame surrounding the load bearing column and temporarily attachable thereto in a manner permitting a tilting of said first frame about a horizontal axis disposed centrally relative to the column, said first frame having two opposite side members rotatable relative to the frame about horizontal axes parallel to the tilting axis of the frame, said rotatable side members having means for the alternative connection to said rotatable side members of two lifting rods located on opposite sides of said column or the jacks associated with said lifting rods.

14. The method of claim 13, wherein said connecting member comprises an additional,

second frame surrounding said column inside said first frame, said second frame being displaceable along the column and temporarily attachable thereto in a fixed relationship, said first frame being pivoted to said second frame about said horizontal axis.

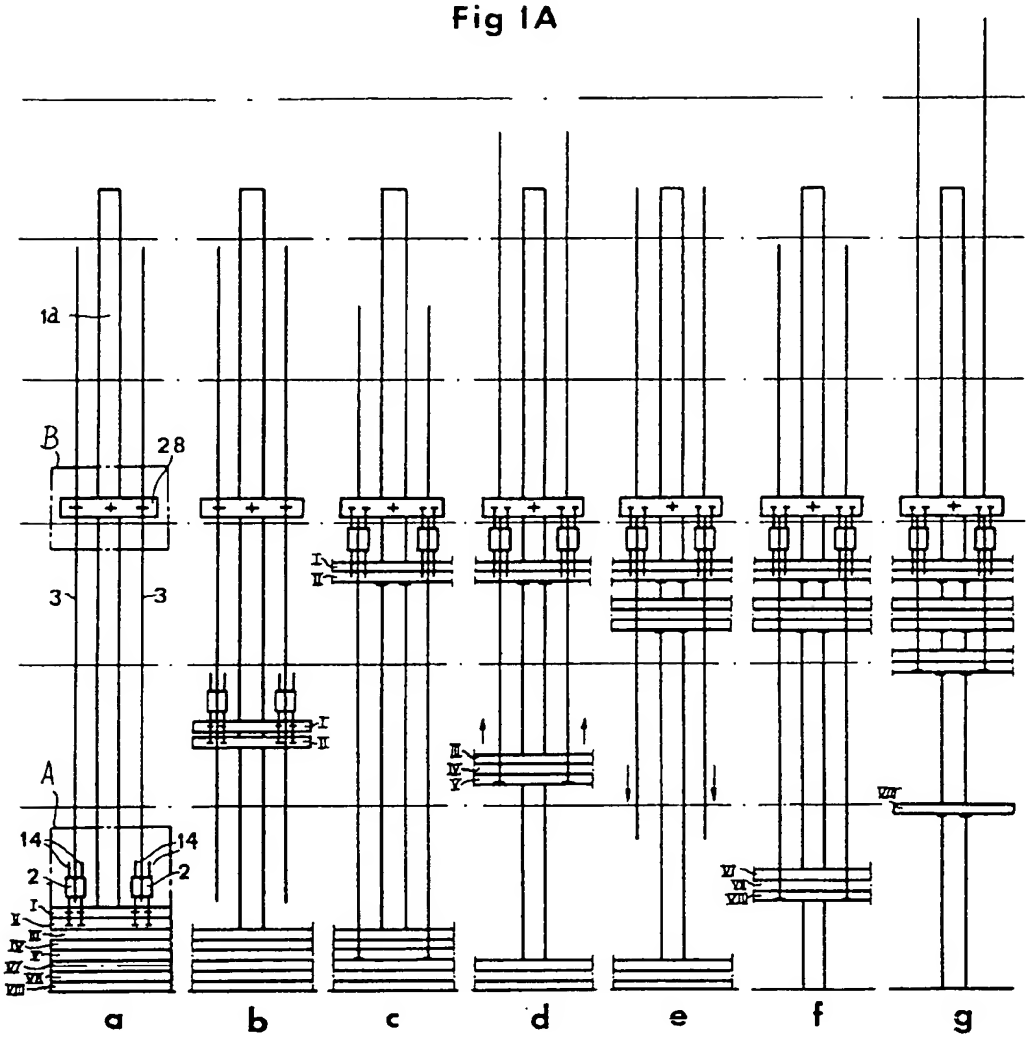
15. The method of any of claims 1 to 14, wherein means for supplying hydraulic fluid to the jacks and control means for the jacks are mounted upon the uppermost slab to be lifted.

16. The method of erecting a multi-storey building having floor slabs connected to vertically extending load bearing members, substantially as hereinbefore described and illustrated in the accompanying drawings.

MARKS & CLERK.

Berwick-upon-Tweed: Printed for Her Majesty's Stationery Office by The Tweeddale Press Ltd. 1967.
Published at the Patent Office, 25 Southampton Buildings, London, W.C.2 from which copies may be obtained.

Fig 1A



1,065,542
4 SHEETS

COMPLETE SPECIFICATION

This drawing is a reproduction of the Original on a reduced scale.

SHEETS 1 & 2

Fig 1B

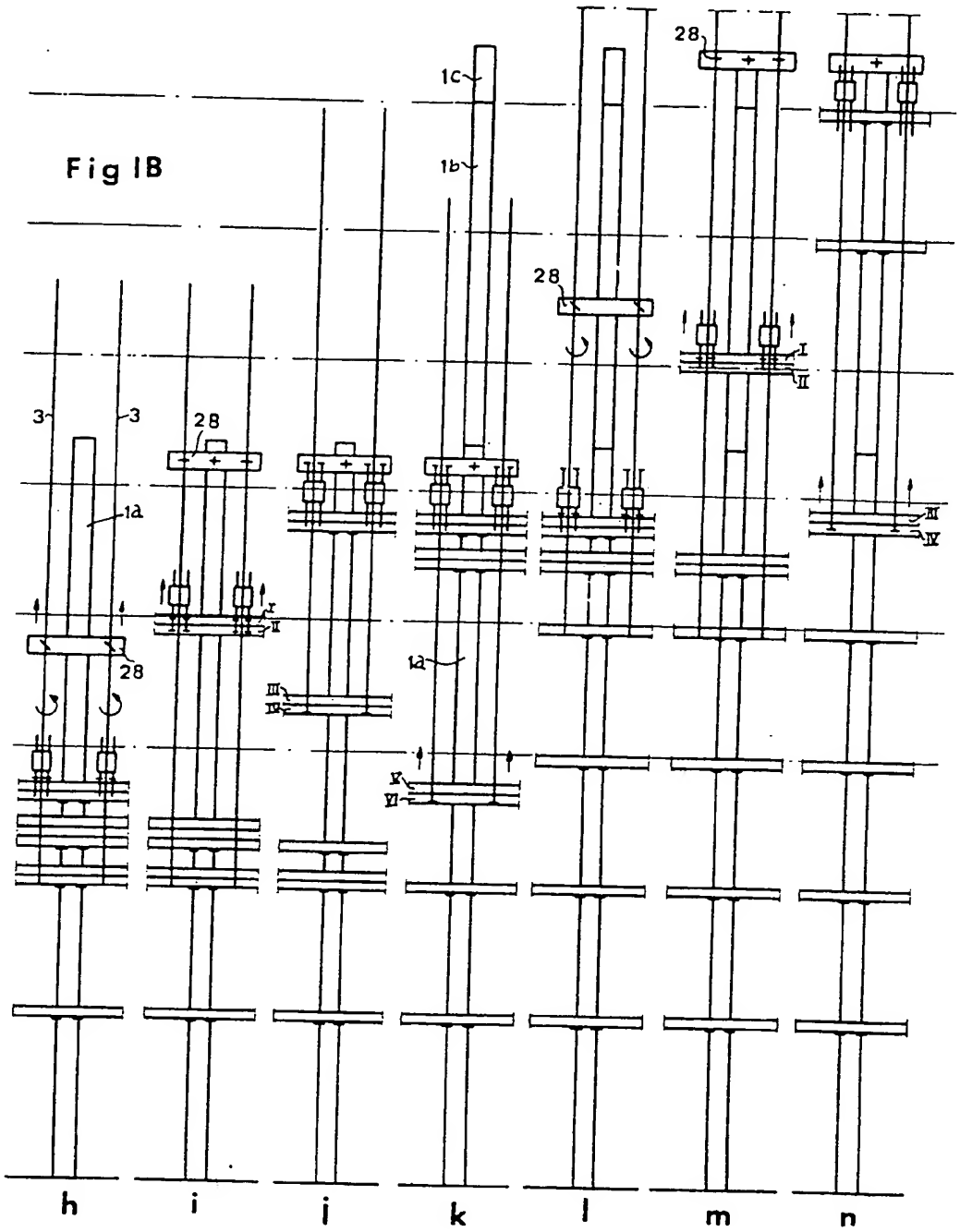
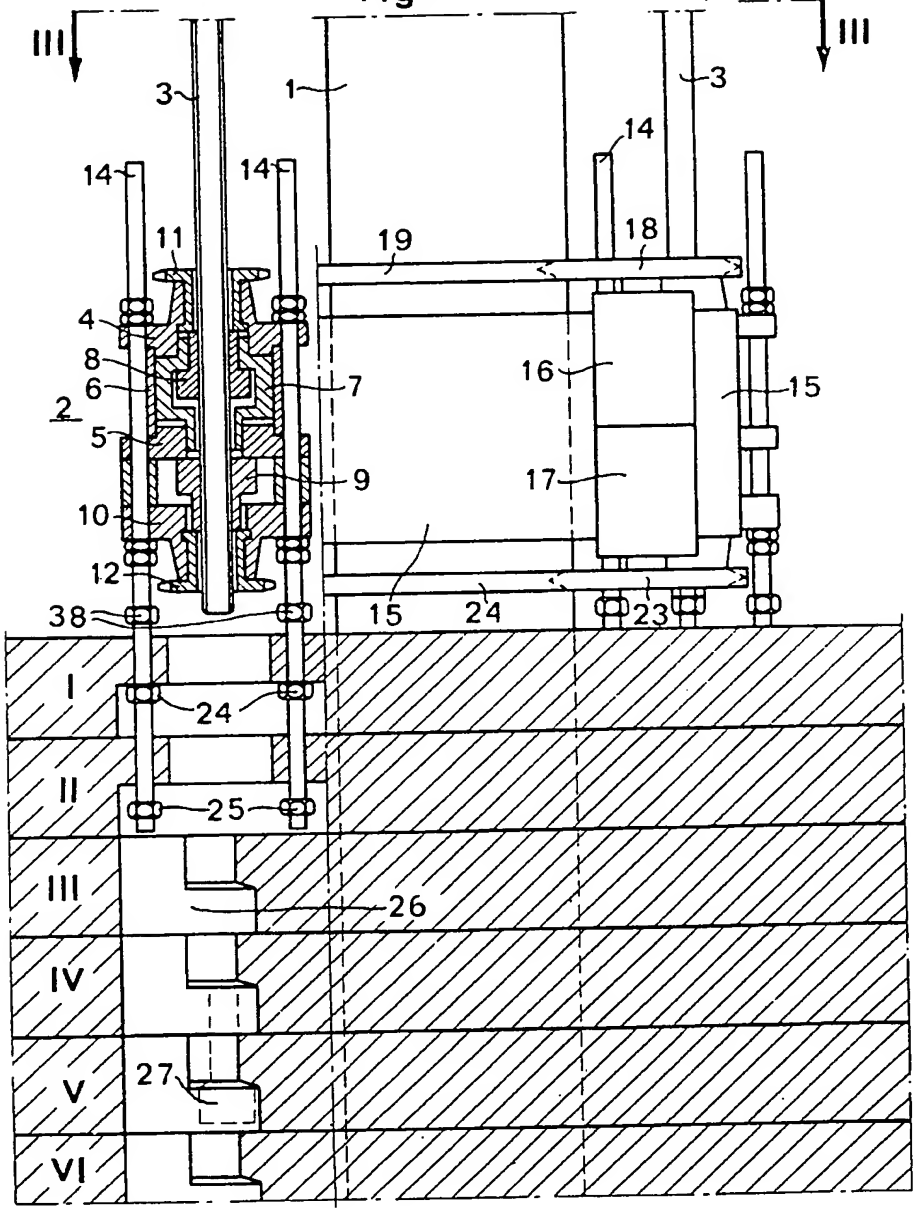


Fig 2


III
III
3
1
3
14
14
14
11
19
18
4
8
6
2
5
7
16
15
9
17
10
12
38
15
24
23
I
24
II
25
III
26
IV
V
27
VI

1,065,542
4 SHEETS

COMPLETE SPECIFICATION

This drawing is a reproduction of the Original on a reduced scale.
SHEETS 3 & 4

Fig 3

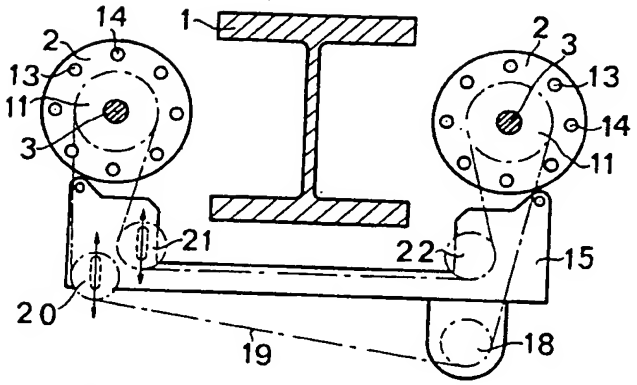


Fig 4

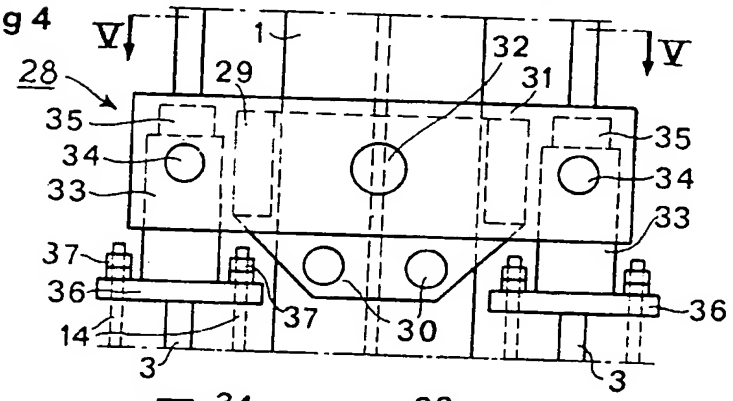


Fig 5